3.20 ANTENNA GAIN

There are two types of antenna modeling in ESAMS. The track-while-scan (TWS) radars use a simple table lookup, while the others use a four-beam monopulse algorithm. In the monopulse algorithm, the positions of the four beams are specified by a squint angle (angle off-boresight) and a rotation angle as illustrated in Figures 3.20-1 and 3.20-2. By default, the rotation angles are 45, 135, 225, and 315 degrees.

Each of the four component beams is assumed to have a sin (x)/x beamshape with the beamwidth specified by a half-power angle, θ hp, (HPANG) and gain computed from:

$$G = 4\pi\varepsilon / \theta_{hp}^{2} \qquad [3.20\text{-}1]$$

where ε is the antenna efficiency.

The functions of the antennas are to directionally transmit signals and to receive target and clutter-reflected signals. The antenna function is modeled as a gain, relative to an omnidirectional antenna, and is sensitive to off boresight angles due to the shape of the sin(x)/x function. Geometric transformations must be accomplished for the energy received by the four horns of the antenna to reflect values that would be injected from an off-boresight target.

While antenna patterns can be specified in tables or based upon the sin (x)/x function, the latter method is attractive when the specific gain features of an antenna system are unknown. In this instance, the user can specify squint angle, rotation angle, half-power angles, and antenna efficiency, and the model performs three calibrations to produce the desired magnitudes:

a. Normalization of the sum channel response to 1;

b. Calculation of the azimuth and elevation error slope factors to determine error angle from measured response; and

c. Calculation of the on-axis antenna sum channel gain.

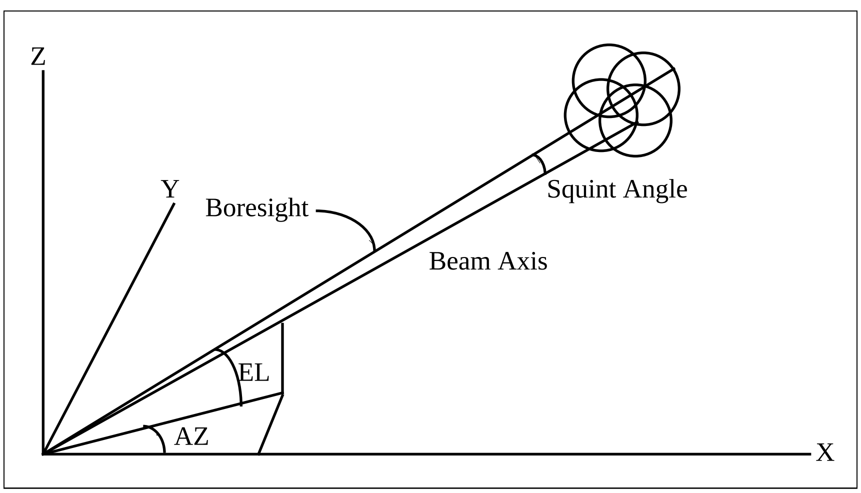

FIGURE 3.20-1. Monopulse Antenna Geometry.

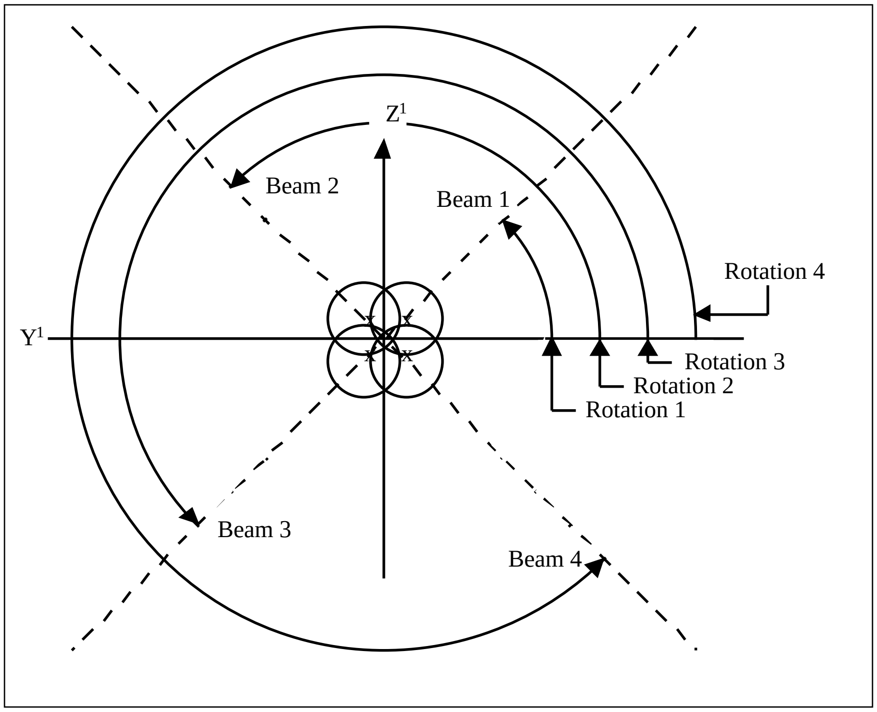

FIGURE 3.20-2. Rotation Angles.

Gain curves, as a function of off-boresight angle for corresponding sum and difference patterns, are shown in Figures 3.20-3 and 3.20-4.

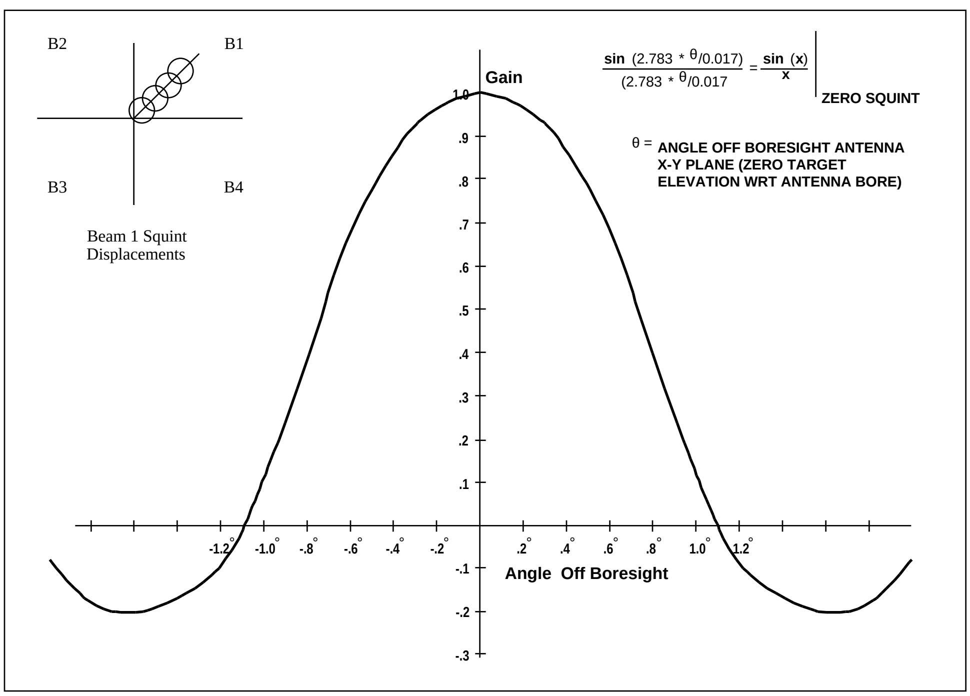

FIGURE 3.20-3. Monopulse Radar Sum Pattern.

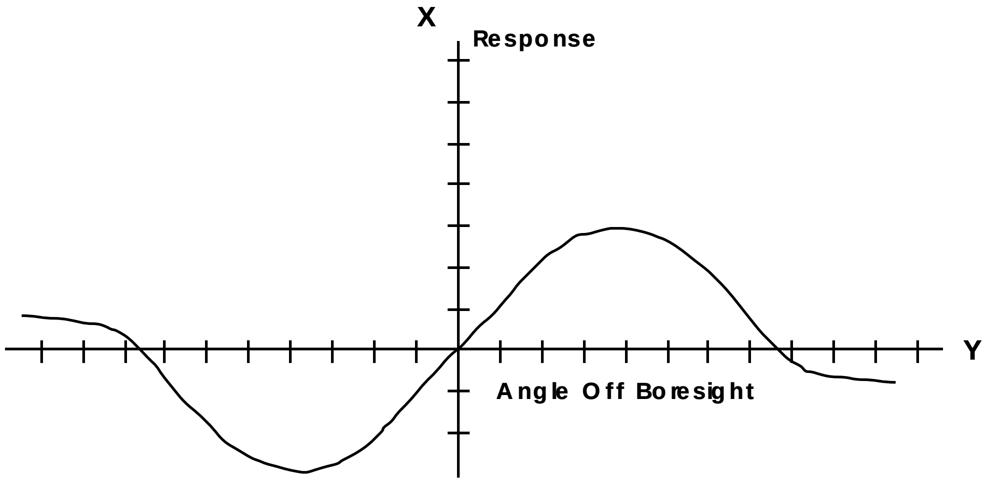

FIGURE 3.20-4. Monopulse Radar Difference Pattern.

Data requirements for measurement of antenna gain as a function of off-boresight angle are listed in Table 3.20-1.

TABLE 3.20-1. Antenna Gain Data Requirements.

Data Item		Accuracy	Sample Rate	Comments
5.1.1	Off boresight azimuth	±0.1°	0.1° (0° to ±2 x BW) 1° (to ±2 x BW to 45°) 5° (45 to 90°)	
5.1.2	Off boresight elevation	±0.1°	0.1° (0° to ±2 x BW) 1° (to ±2 x BW to 45°) 5° (45 to 90°)	
5.1.3	Signal input	±0.5 dB	10 Hz	Mean value to antenna
5.1.4	Signal output	±0.5 dB	10 Hz	Mean value from antenna

3.20.1 Objectives and Procedures

Two characteristics of the antenna pattern modeling in ESAMS are important for the prediction of the SAM effectiveness. One is the maximum gain of the antenna and the other is the beamshape. The maximum (boresight) antenna gain in ESAMS is calibrated to a value of 46.14 dBi as given in Equation [3.20-1] with a half-power angle of 1 deg and an antenna efficiency of 1.0. Variations in half-power angle and antenna efficiency change the magnitude of the antenna gain, and hence the received signal power in accordance with the radar range equation and does not need to be explicitly examined.

The sin(x)/x beamshape used in ESAMS for all non-TWS radars is known to be only an approximation to actual threat beamshapes; therefore, the objective of these sensitivity analyses is to examine the effect of varying the squint angle and half-power angle.

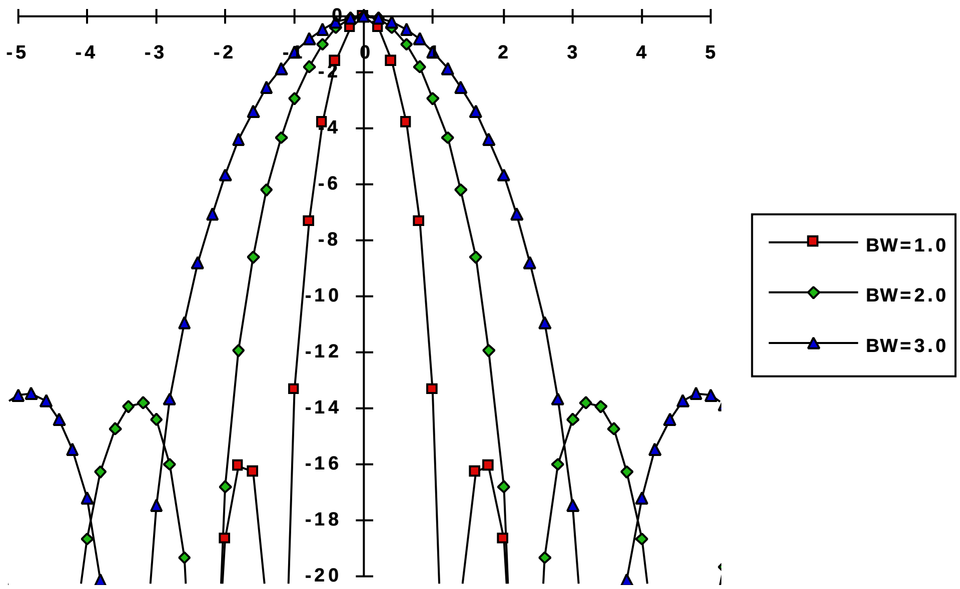

FIGURE 3.20-5. Antenna Beamshapes for Different HPANG.

The ESAMS antenna beamshape is also significantly impacted by the off-boresight, squint angle of the component beams. If the squint angle is sufficiently large with respect to the half-power angle, the maximum gain will occur at off-boresight angles. Moreover, the sidelobe angles and gains vary in a complicated and non-intuitive way as illustrated in figure 3.20-6.

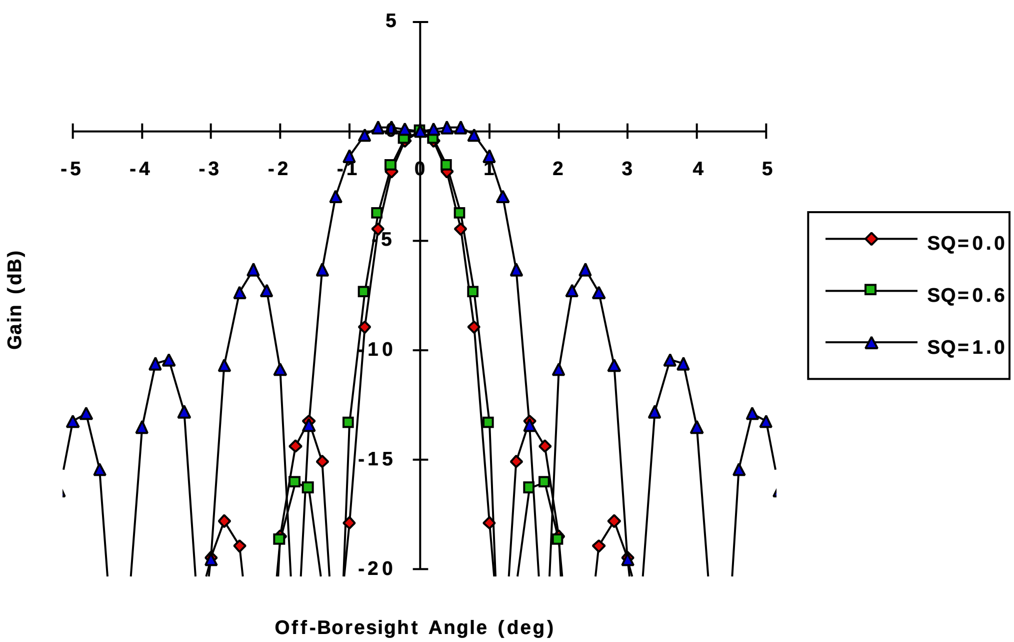

FIGURE 3.20-6. Antenna Beamshapes for Different Squint Angles.

The antenna beamshape has a relatively small effect on target tracking for engagements that are signal-limited rather than clutter-limited. This is because only the resolution of the antenna difference pattern is affected. In order to examine the sensitivity of ESAMS to antenna beamshape, it is necessary to use a measure that is more sensitive to the off-boresight antenna gain, such as clutter power.

3.20.2 Results

Clutter power is an appropriate measure for antenna beamshape, and clutter power as a function of beamwidth is plotted in Figure 3.20-7. Because the gain of the component beams is inversely proportional to the square of the half-power angle, the antenna efficiency was changed in order to specify three beamshapes with 1, 2, and 3 degree half-power angles but with equal gains. These were specified as:

HPANG	ANTEF
1.0	0.6
2.0	2.4
3.0	5.4

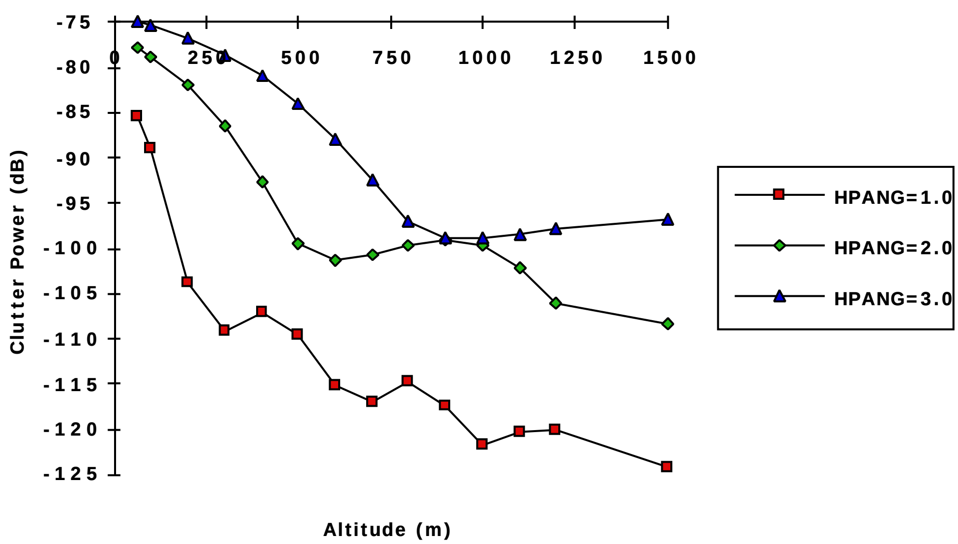

FIGURE 3.20-7. Clutter Power vs. Altitude for Different Beamwidths.

Clutter powers shown above were computed for a monopulse radar with an antenna height of 26m using the default terrain type (TTYPE=3) and a target ground range of 20km. As expected, the larger beamwidths yielded significantly more clutter. The maxima and minima are a consequence of the sidelobe structure for the corresponding beamshape (as shown in Figure 3.20-6).

3.20.3 Conclusions

The ESAMS user has some flexibility to change both the maximum antenna gain and the antenna beamshape using model input parameters. The calibration of maximum gain to intelligence assessments or measured data is straightforward using the antenna efficiency parameter. Calibrating antenna beamshapes is more difficult. The problem is variations in half-power and squint angles often result in unexpected changes in beamshape. For example, variations in squint angle result in non-monotonic changes in sidelobe level as illustrated in Figure 3.20-7.

For target acquisition and tracking, the radar antenna is usually boresighted on the target, and the antenna beamshape will have a negligible impact unless there is a significant clutter signal competing with the target signal (as e.g. a very low RCS target at low altitude). As the antenna beamwidth widens, more of the terrain will be illuminated and the higher the clutter power will be on the average. Wide beamwidths may also impact the angle error response (volts per degree measured angle error) and degrade tracking accuracy, but this was not explicitly examined.